

PREFACE

When my granddaughter Allison was born, one of the first things I said to her was “Welcome to the universe!” It’s something my coauthor Neil Tyson has said many times on radio and TV. Indeed it is one of Neil’s signature sayings. When you are born, you become a citizen of the universe. It behooves you to look around and get curious about your surroundings.

Neil felt a call from the universe on a first visit to the Hayden Planetarium in New York City when he was 9 years old. As a city kid, he saw the glories of the nighttime sky for the first time displayed on the planetarium dome and decided at that moment to become an astronomer. Today he is the director of that institution.

In fact, we are all touched by the universe. The hydrogen in your body was forged in the birth of the universe itself, while the other elements in your body were made in distant, long-dead stars. When you call a friend on your mobile phone, you should thank astronomers. Mobile phone technology depends on Maxwell’s equations, whose verification depended on the fact that astronomers had already measured the speed of light. The GPS that tells your phone where you are and helps you navigate relies on Einstein’s theory of general relativity, which was verified by astronomers measuring the deflection of starlight passing near the Sun. Did you know there is an ultimate limit to how much information can ever be stored in a 6-inch-diameter hard drive and that it depends on black hole physics? At a more mundane level, the seasons you experience every year depend directly on the tilt of Earth’s axis relative to the plane of its orbit around the Sun.

This book aims to better acquaint you with the universe in which you live. The idea for this book started when the three of us taught a new undergraduate course on the universe for nonscience majors at Princeton University—for students who perhaps had never taken a science course before. For this purpose, Neta Bahcall, our colleague and director of undergraduate studies, selected Neil deGrasse Tyson, Michael Strauss, and me. Neil’s genius at explaining science to nonscientists was apparent, Michael had just discovered the most distant quasar yet found in the universe, and I had just received the university’s President’s Award for Distinguished Teaching. The course was launched with great fanfare and attracted so many students that we couldn’t hold it in our own building and had to move it to the biggest lecture hall in the Physics Department. Neil talked about “Stars and Planets,” Michael talked about “Galaxies and Quasars,” and I talked about “Einstein, Relativity, and Cosmology.” The course was mentioned in *Time* magazine, when *Time* honored Neil as one of the 100 most influential people in the world in 2007. Among other features of this book, you will get to know Neil as a professor, telling you things he tells his students.



FIGURE 0.1. The three authors, left to right: Strauss, Gott, and Tyson.
Photo credit: Princeton, Denise Applewhite

After we had taught the course for a number of years, we decided to put its ideas down in the form of a book for readers who hungered for a deeper understanding of the universe.

We give you a tour of the universe from an astrophysical point of view, from the point of view of trying to understand what is going on.

We tell you how Newton and

Einstein got their greatest ideas. You know Stephen Hawking is famous. But we tell you what made him famous. The great movie of his life story, *The Theory of Everything*, won Eddie Redmayne a best actor Oscar for his compelling portrayal of Hawking. It shows Hawking having his greatest idea by simply staring into the fireplace and having it suddenly come to him. We tell you what the movie left out: how Hawking didn’t believe the work of Jacob Bekenstein, but he ended up reaffirming it and taking it to an entirely new conclusion.

And that's the same Jacob Bekenstein who found the ultimate limit for how much information could be stored on your 6-inch-diameter hard drive. It's all connected. In this book, of all the topics in the universe, we focus particularly on those we are most passionate about, and we hope our excitement will be contagious.

Much has been added to astronomical knowledge since we began, and this book reflects that. Neil's views on the status of Pluto have been ratified by the International Astronomical Union, in a historic vote in 2006. Thousands of new planets have been discovered circling other stars. We discuss them. The standard cosmological model, including normal atomic nuclei, dark matter, and dark energy, is now known with exquisite accuracy, thanks to results from the Hubble Space Telescope, the Sloan Digital Sky Survey, and the Wilkinson Microwave Anisotropy Probe (WMAP) and Planck satellites. Physicists have discovered the Higgs Boson at the Large Hadron Collider in Europe, bringing us one step closer to the hoped for theory of everything. The Laser Interferometer Gravitational-Wave Observatory (LIGO) experiment has made a direct detection of gravitational waves from two inspiraling black holes.

We explain how astronomers have determined how much dark matter there is, and how we know that it is not made of ordinary matter (with atomic nuclei containing protons and neutrons). We explain how we know the density of dark energy, and how we know that it has a negative pressure. We cover current speculations on the origin of the universe and on its future evolution. These questions bring us to the frontiers of physics knowledge today. We have included spectacular images from the Hubble Space Telescope, the WMAP satellite, and the New Horizons spacecraft—showing Pluto and its moon Charon.

The universe is awesome. Neil shows you that in the very first chapter. This leaves many people thrilled, but feeling tiny and insignificant at the same time. But our aim is to empower you to understand the universe. That should make you feel strong. We have learned how gravity works, how stars evolve, and just how old the universe is. These are triumphs of human thought and observation—things that should make you proud to be a member of the human race.

The universe beckons. Let's begin.

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